GENERAL DYNAMICS | CONVAIR

Report No. 8926-159

Material - Magnesium - AZ91 Casting

Evaluation of Non-Destructive Inspection Procedures

P. W. Bergstedt, H. C. Turner, W. M. Sutherland

13 March 1957

Published and Distributed
under
Contract AF33(657)-8926

Post Office Box 1950, San Diego 12, California 296-6611
Material Post Office Box 2071 273-6000 | Accounting Post Office Box 510

Report No. 8926-159

Material - Magnesium - AZ91 Casting

Evaluation of Non-Destructive Inspection Procedures

Abstract:

The multi-ribbed framework for the F-102A airplane speed brake door is an AZ91 magnesium alloy casting about 2-1/2 feet wide by 4-1/2 feet long. This complex casting, which essentially is a lattice of thin-walled ribs, is heat treated and aged prior to end use. Since excessive porosity was encountered with a large number of castings, correlations of the casting strengths with the results of dye-penetrant and radiographic inspection were required. As a result of comparisons of tensile strength data with dye-penetrant and radiographic inspections, the following conclusions were drawn: (1) dye-penetrant inspection is inadequate for determining acceptable limits of casting porosity; and (2) x-ray ratings correlated very well with tensile test results. Radiographic inspection thus was considered the more reliable inspection method.

Reference: Bergstedt, P. W., Turner, H. C., Sutherland, W. M., "Speed Brake Casting, 8-73673, Evaluation of," General Dynamics/Convair Report MP 56-216, San Diego, California, 13 March 1957. (Reference attached).

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

ENGINEERING TEST LABORATORIES

REPORT 56-216
DATE 3-13-57
MODEL F-102A

TITLE

REPORT NO. 56-216
SPEED-BRAKE CASTING, 8-73673-
EVALUATION OF

MODEL: F-102A

PREPARED BY P. W. Bergstedt
P. W. Bergstedt

GROUP MATERIALS & PROCESSES LAB.

REFERENCE

CHECKED BY: H. C. Turner
H. C. Turner

CHECKED BY: W. M. Sutherland
W. M. Sutherland,
Group Engineer,

APPROVED BY E. F. Strong
E. F. Strong
Chief, Engineering
Test Laboratories

NO. OF PAGES 17

NO. OF DIAGRAMS 14

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

FORM 1612A-4

REPORT NO. 56-216
SPEED BRAKE CASTING, 8-73673
EVALUATION OF

INTRODUCTION:

Part No. 8-73673 is a multi-ribbed framework for the speed brake door of the F-102A. The casting is roughly 2 1/2 ft. wide and 4 1/2 ft. long; it is cast from AZ91 magnesium alloy and subsequently heat treated and aged. Although the complexity of the problems associated with the fabrication of these castings can be readily appreciated, many of the parts received at Convair were found to possess an inordinate amount of porosity. This report describes the evaluation tests which were made on three (3) of the castings.

OBJECT:

To determine the efficiency of dye-penetrant and radiographic inspection as methods of rating casting quality.

CONCLUSIONS:

The tensile tests of specimens cut from the castings led to the following conclusions:

1. Dye-penetrant inspection cannot be considered an adequate method of determining the acceptable limits of casting porosity.
2. As anticipated, X-ray ratings correlated very well with tensile test results. Radiographic testing is much more trustworthy than dye-penetrant examination as a non-destructive test of such porous materials.

PROCEDURE:

Three castings, identified by X-ray No., were included in this investigation. After dye-penetrant examination, rough specimen outlines were scribed on the metal in areas which exhibited varying amounts of dye "bleed-out". The parts were then cleaned and marked for sampling as shown in Figures 1, through 3. In all, twenty-nine specimens were removed from the three castings; No. 18 proved to be too small for test purposes and was discarded.

The coupons were machined to standard 0.5-inch gauge width, but the original surfaces were not disturbed along the flat sides of the samples. In the instances where adjoining ribs entered the gauge section, the ribs were simply cut off outside the fillets.

The samples were then inspected and rated by the Process Control Department. The dye-penetrant method requires approval or rejection by an experienced inspector. Photographs of all of the coupons are shown in Figures 4 through 10; the pictures were taken shortly after the dye-penetrant examination and with the developer coating still intact.

PROCEDURE: (Continued)

The grading system employed in the X-ray ratings is based upon a series of filmed standards prescribed by ASTM Standard E98-53T. According to this comparison type of evaluation, Grade 1 would be free of defects, Grade 2 acceptable, Grade 3 acceptable but questionable, and Grade 4 would be rejectable. (This type of procedure enjoys wide-spread usage).

No X-rays were taken of coupons removed from the static-test casting - specimens 18 through 29.

Tensile testing was accomplished by the Physical Test Section using the 12,000 lb. Tinius Olsen Machine.

From the broken tensiles, small sections were then cut from the fracture areas and grouped in plastic mounts for polishing - two or three samples per mount. In each case the prepared surface represented an internal portion of the sample, perpendicular to the fracture, and extending 1/4" to 3/8" from the fracture.

RESULTS AND DISCUSSION:

The tensile properties and inspection ratings of the coupons are shown in Table I. The "Correlation" column was based upon an overall appraisal of ratings vs. actual properties for each specimen.

The dye-penetrant technique proved to be useful for rejecting material, but the method could not be used in a positive sense - too many spongy samples were apparently acceptable.

Radiographic inspection was much more reliable as a means of estimating acceptable limits of micro-shrinkage. Since X-rays can detect internal voids which are not connected to the surface, the advantage of this method in applications of this type is readily understood and accepted. It is unfortunate that the X-ray examination did not include the group of specimens from the static-test casting.

A study of the photomicrographs disclosed many regions of localized porosity and/or mechanical tears. Each photograph represents only a small portion of a particular sample and often tends to exaggerate the extent of the defects. The economical practice of placing more than one sample in a single plastic mount led to considerable difficulty in producing an even polish on the relatively soft magnesium samples. Consequently, only one photomicrograph is included in the report for each of the described conditions (Figures 11 through 17).

NOTE: This report was prepared from data recorded in Laboratory Record Book No. 910.

CONVAIR
SAN DIEGO

FORM 73

TABLE I. MECHANICAL PROPERTIES & INSPECTION RATINGS OF TENSILE SAMPLES FROM AZ91-HTA CASTINGS.

*Specimen No.	Mechanical Properties			Dye Penetrant Rating		Radiographic Rating			Metallographic Rating (Extent of Porosity)	Correlation (Inspection vs. Test)
	F_{ty}, 0.2% offset	F_{tu}	% Elongation 2-in. gage	Acceptable	Reject.	Grade 2	Grade 3	Grade 4		
13	11,130	12,280	1.5		X			X	Severe	Good
28	13,500	13,800	2.5	X		Not X-rayed			Moderate	Poor
2	10,370	14,430	1.5		X			X	Severe	Good
27	13,200	14,500	2.0		X	Not X-rayed			"	"
21	11,100	15,100	3.5		X	" "			"	"
17	10,300	15,200	2.0		X			X	"	"
5	13,900	15,800	— *		X			X	"	"
1	13,600	17,200	2.0		X			X	"	"
26	16,600	17,900	2.0	X		Not X-rayed			Moderate - Severe	Poor
20	15,500	18,700	2.0	X		" "			Moderate	"
29	13,900	18,800	2.0	X		" "			Severe	"
25	16,400	19,400	2.5		X	" "			"	Good
6	13,290	20,560	2.5		X			X	Severe (Localized)	"
11	17,400	21,200	0.5 *	X			X		Moderate - Severe	Fair
24	17,300	21,400	2.0		X	Not X-rayed			Severe (Localized)	Good
12	17,990	21,910	2.5	X				X	Moderate (Torn)	Poor
7	15,900	22,000	1.0		X			X	Moderate - Severe	Good
22	16,300	23,000	2.0	X		Not X-rayed			"	Fair
3	17,300	24,100	0.5	X				X	"	"
10	20,100	24,300	2.0	X			X		Moderate (Torn)	"
4	17,300	27,900	1.5	X		X			Mod.-Sev. (Very Local)	Good
16	17,300	28,500	1.0 *	X			X		Moderate (Torn)	"
8	18,600	29,100	— *	X		X			Slight (Torn)	"
18	18,800	31,100	2.5	X		Not X-rayed			Slight	"
15	17,100	31,900	3.5	X			X		"	"
14	18,100	33,100	3.5	X			X		"	"
9	20,200	33,600	4.0	X			X		Moderate (Local.)	"
23	17,400	34,600	2.0	X		Not X-rayed				"

* Poor testing technique — grip not along axis of coupon.

* Fracture occurred outside of scribed gauge section.

* Grades 2 & 3, "Acceptable" — Grade 4, "Rejectable"

NOTE: Specimens arranged in order of increasing ultimate strength, F_{tu}.

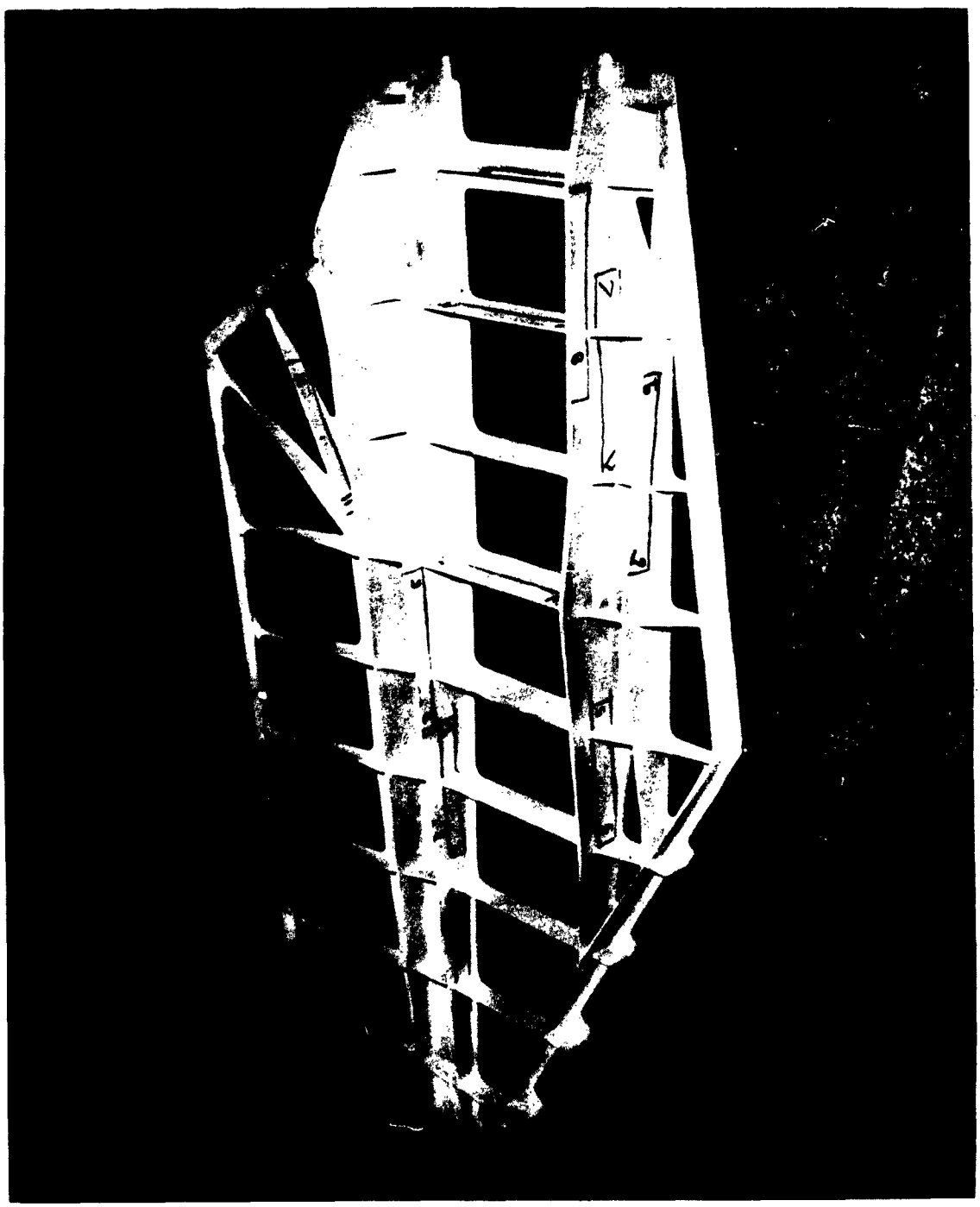

FIGURE 1. PART NO. 8-73673, X-RAY NO. H7315-2 (COUPONS 1-11)

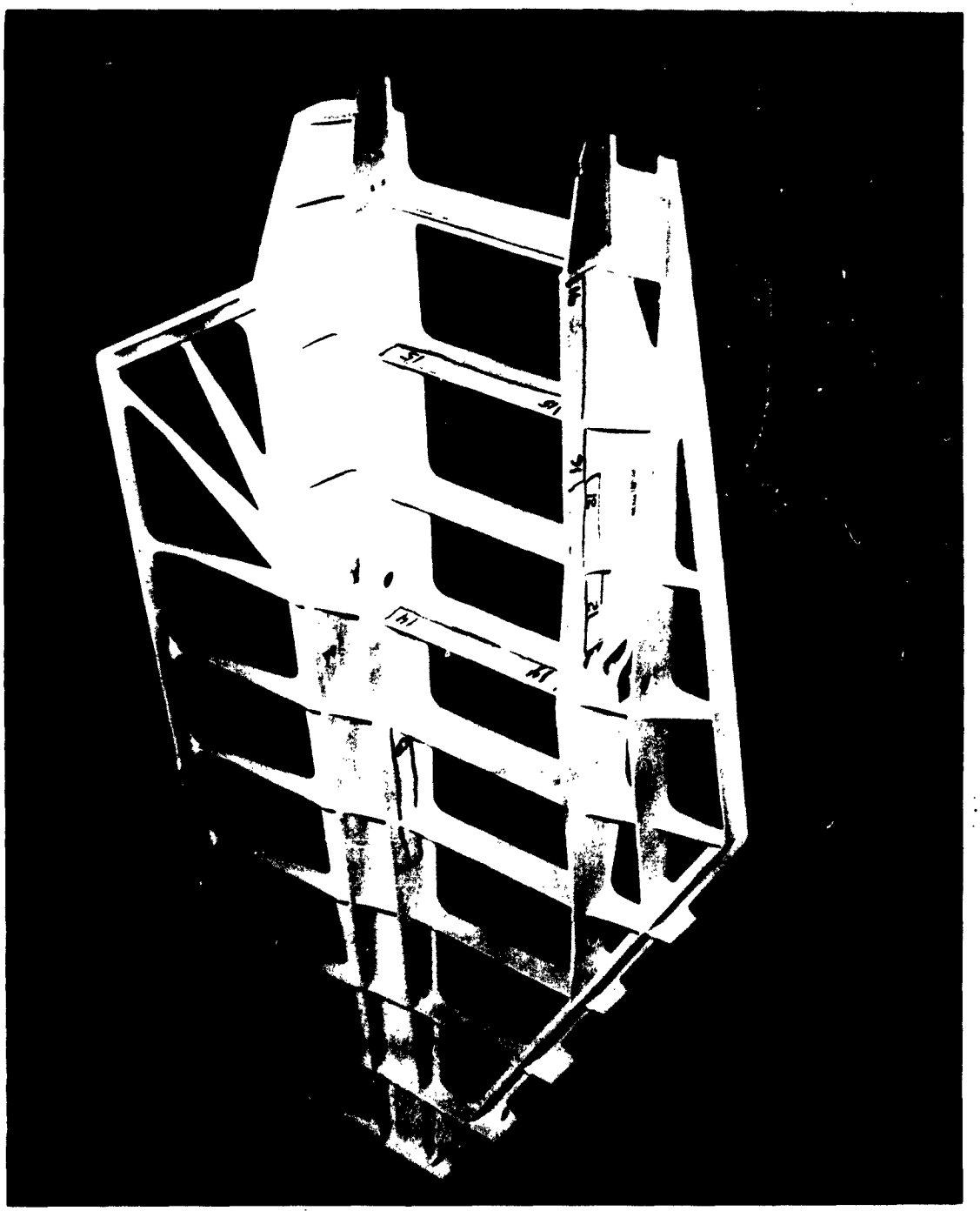

FIGURE 2. PART NO. 8-73673, X-RAY NO. H7315-1 (COUPONS 12-17)

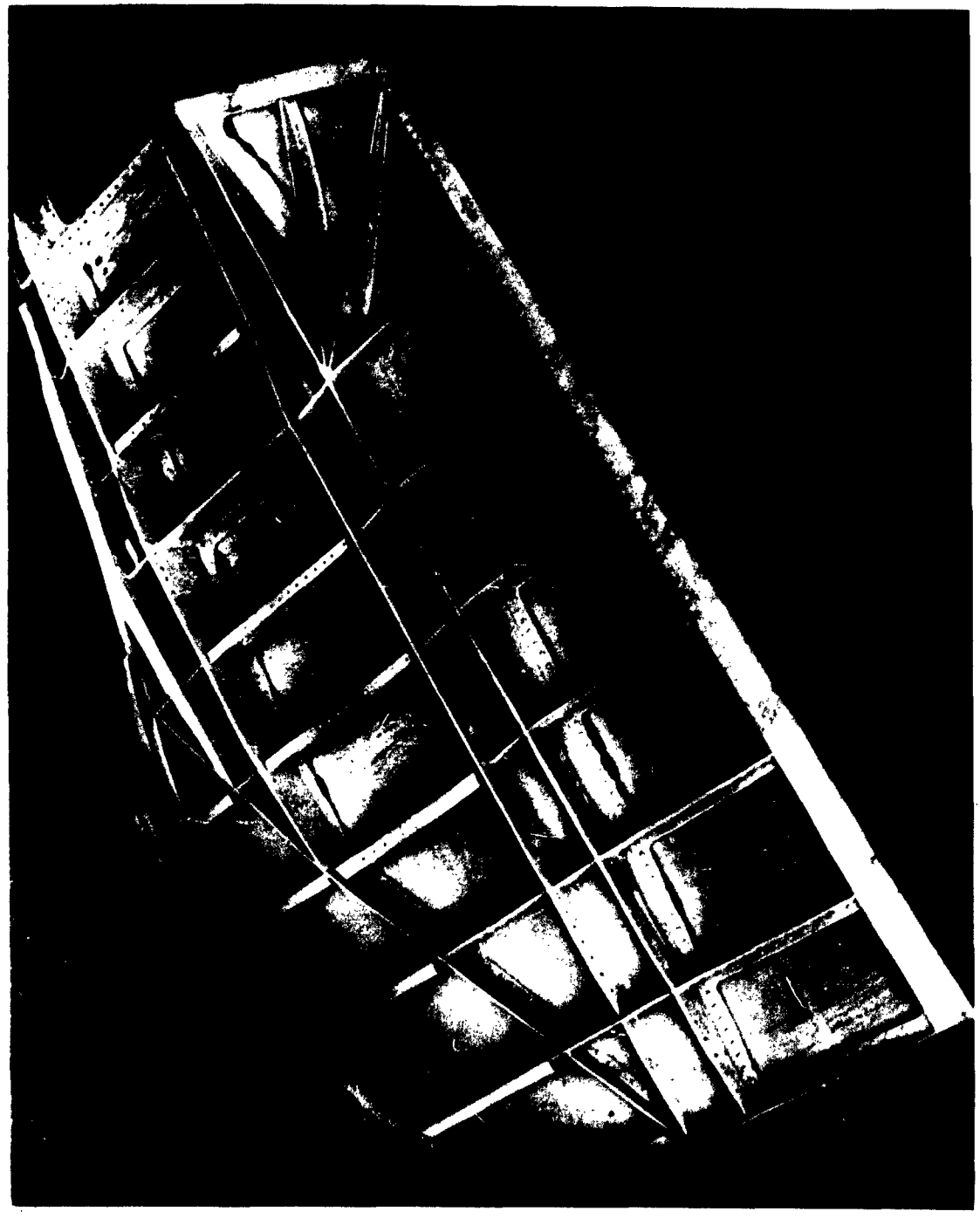

FIGURE 3. STATIC-TEST CASTING, X-RAY NO. H7316-3 (COUPONS 18-29)

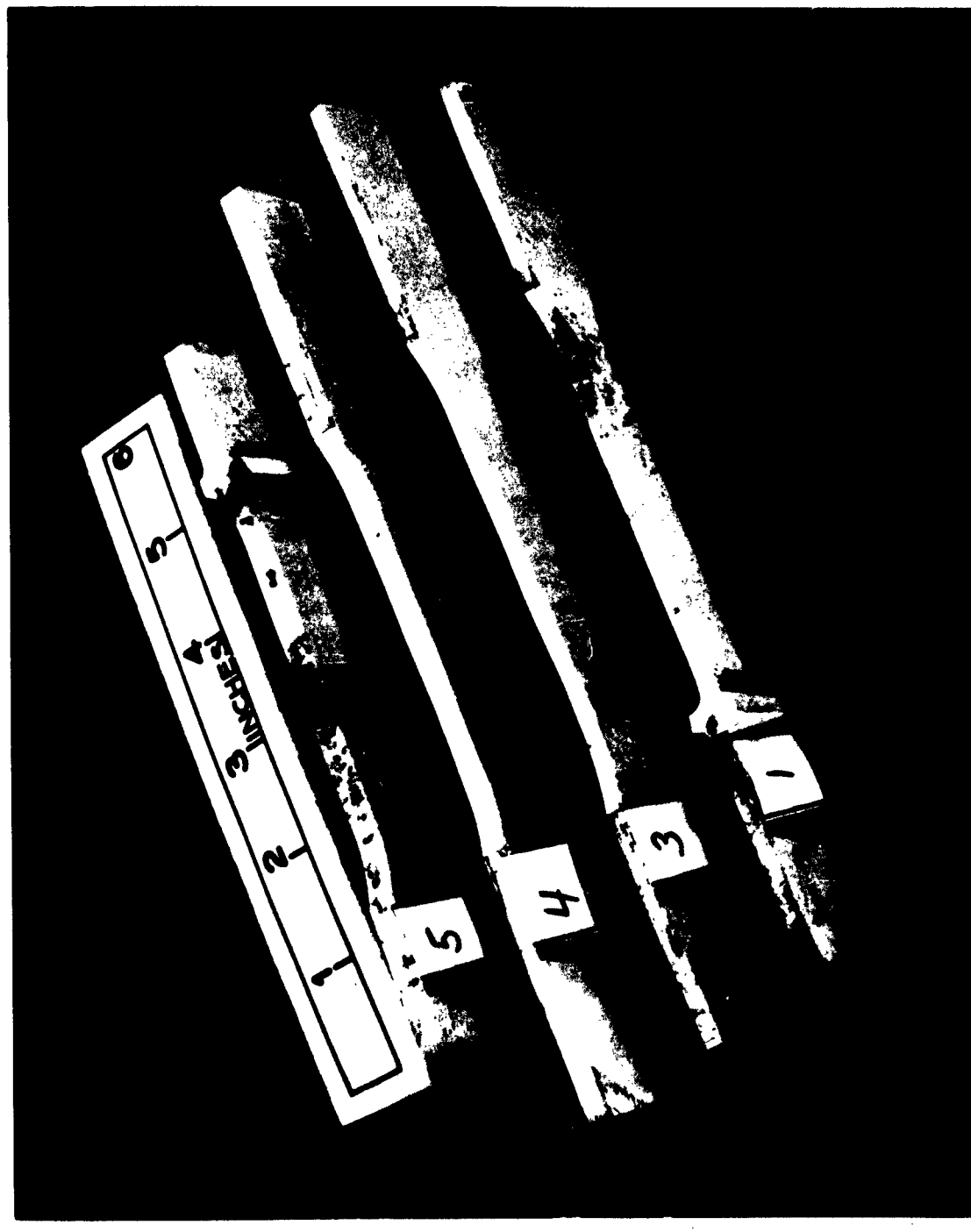

FIGURE 4. COUPONS 1, 3, 4, & 5. (SHOWING DYE INDICATIONS)

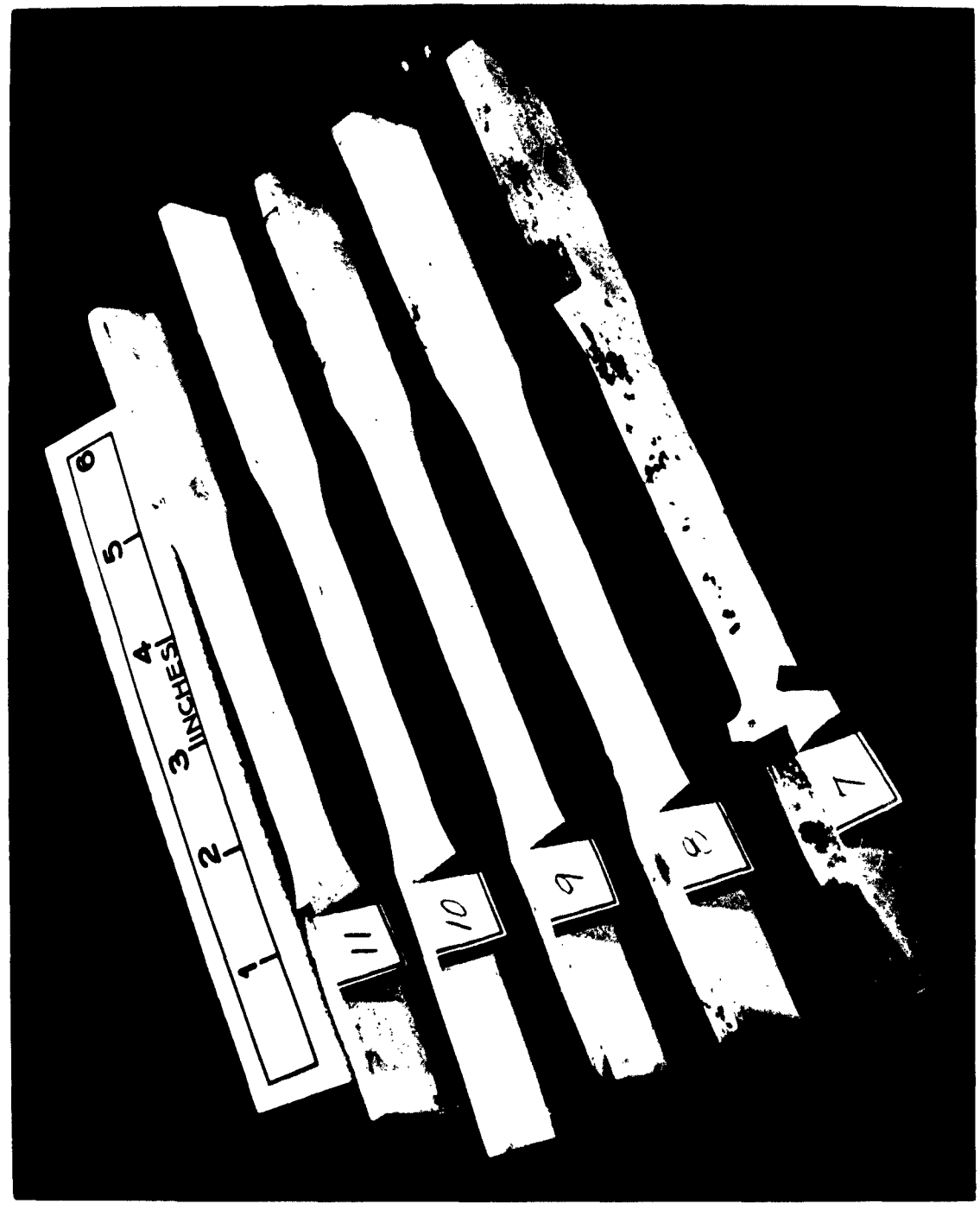

FIGURE 5. COUPONS 7-11 (SHOWING DYE INDICATIONS)

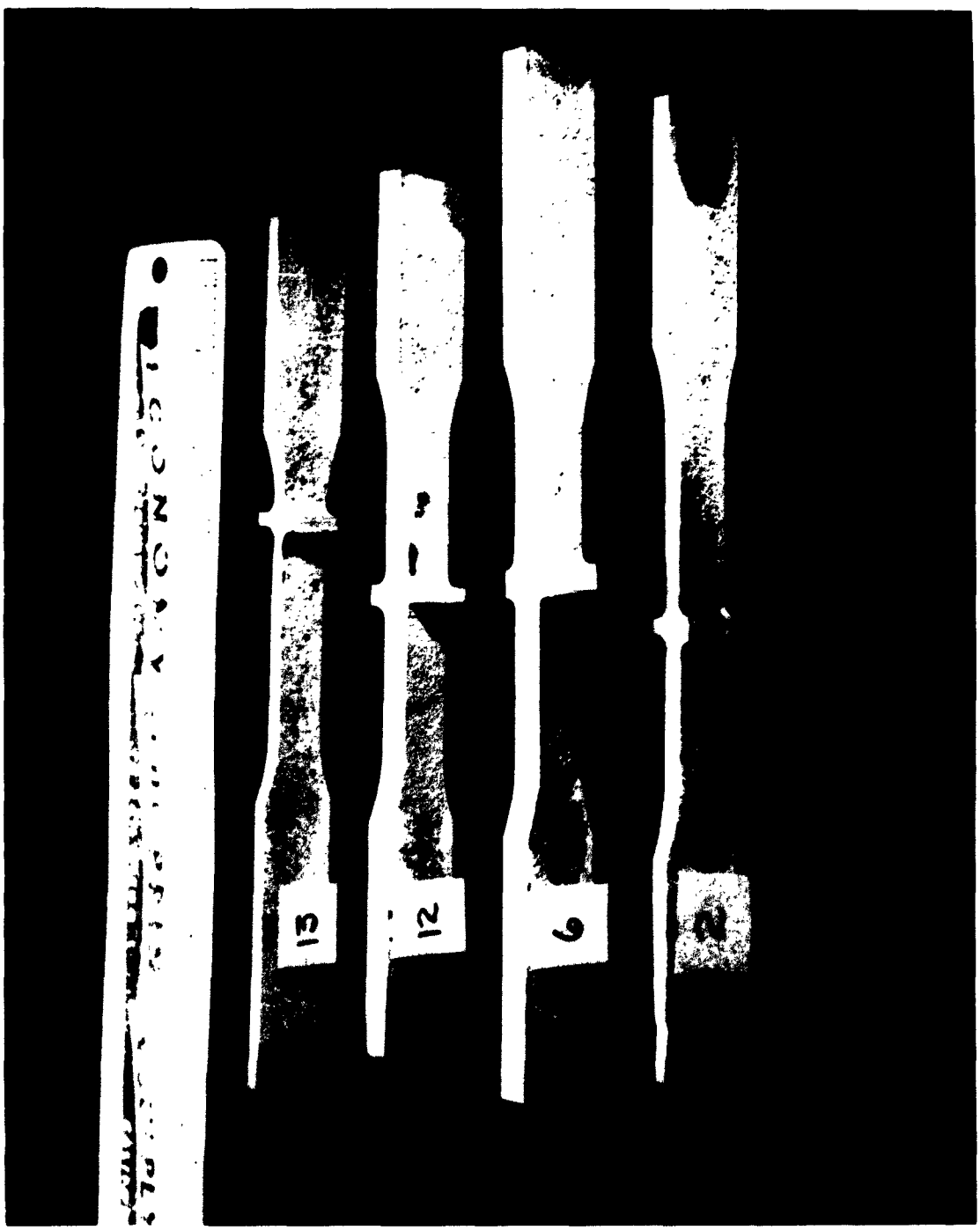

FIGURE 6. COUPONS 2, 6, 12, & 13 (SHOWING DYE INDICATIONS)

FIGURE 7. COUPONS 14-17 (SHOWING DYE INDICATIONS)

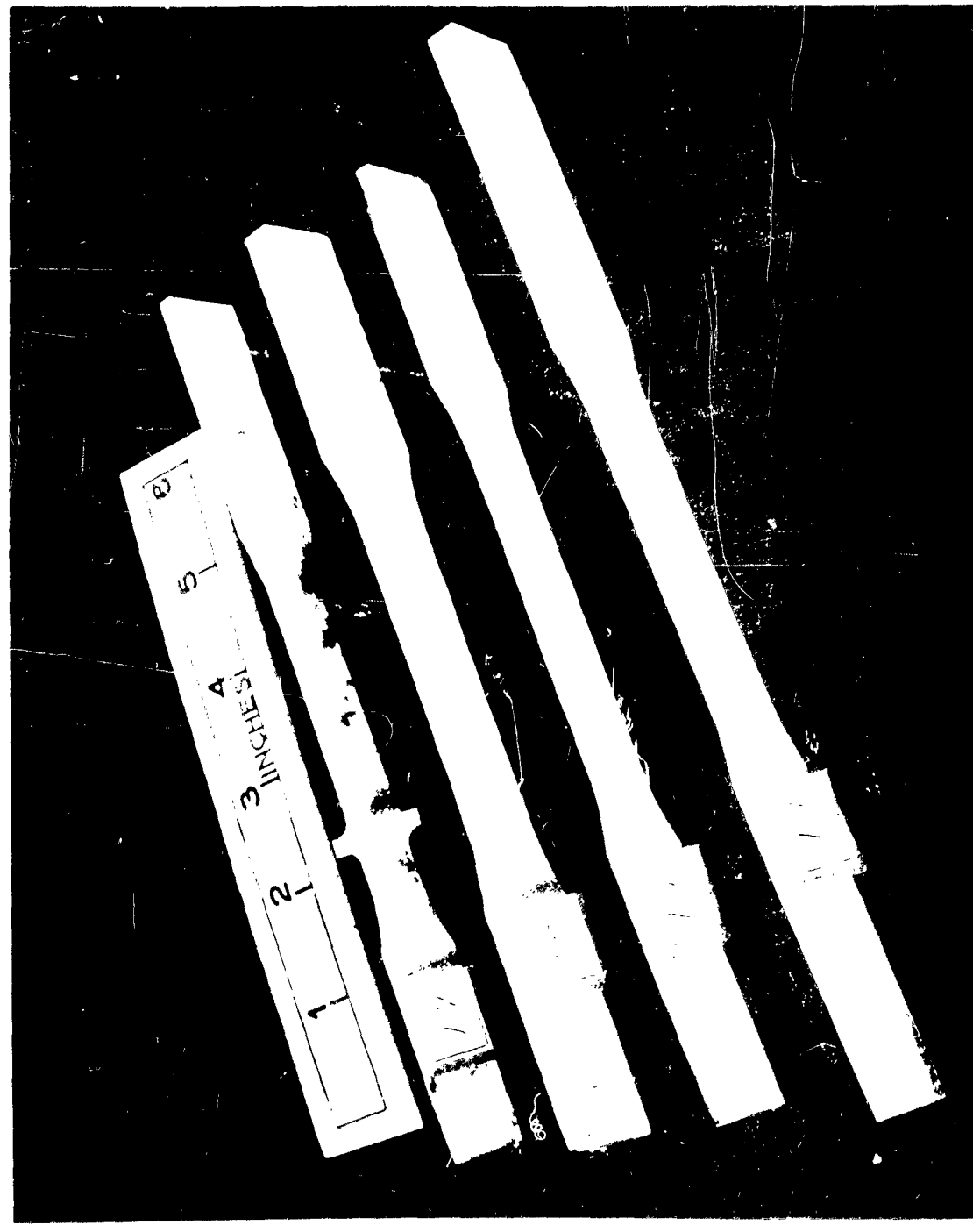

FIGURE 7. COUPONS 14-17 (SHOWING DYE INDICATIONS)

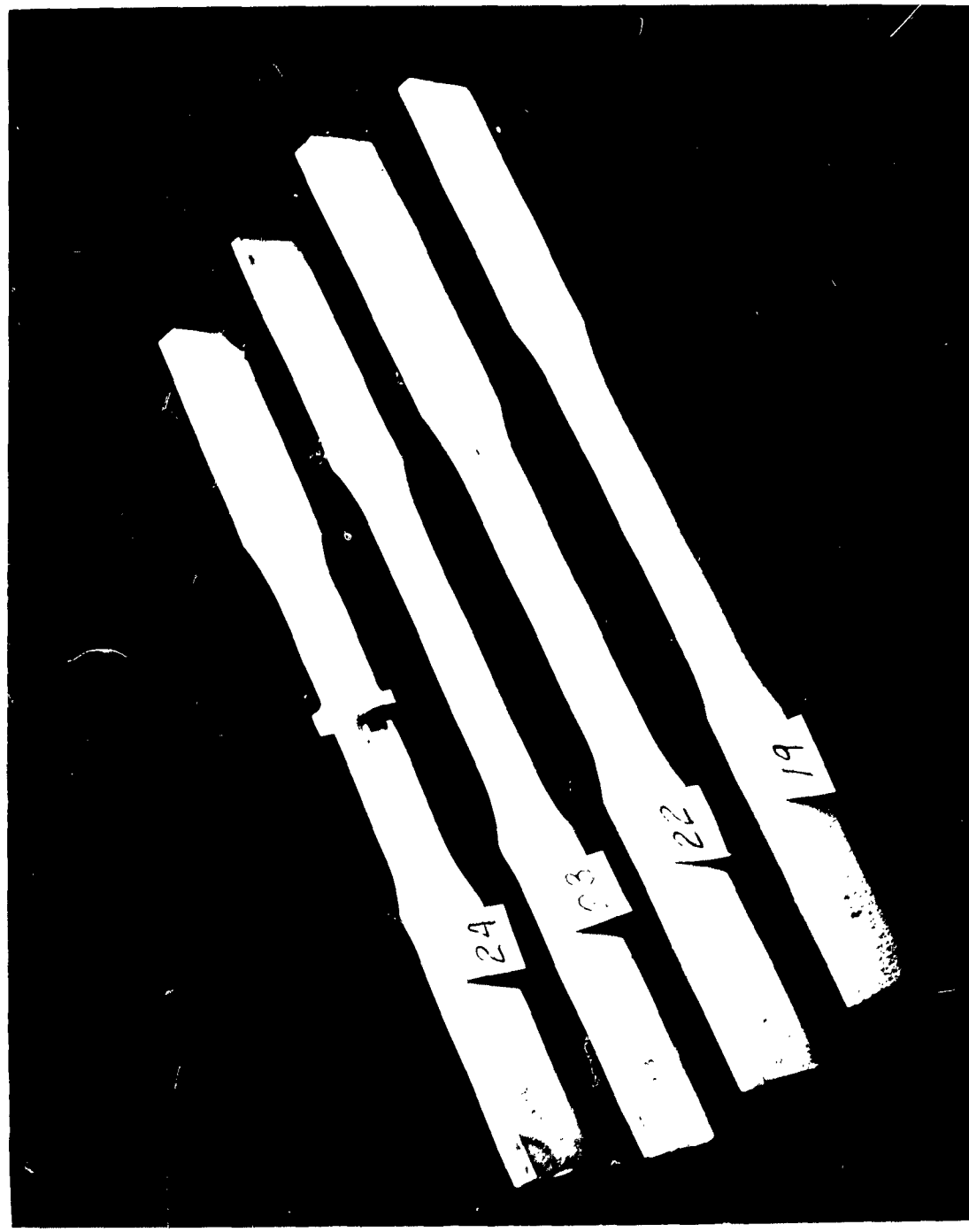

FIGURE 8. COUPONS 19, 22, 23, & 24 (SHOWING DYE INDICATIONS)

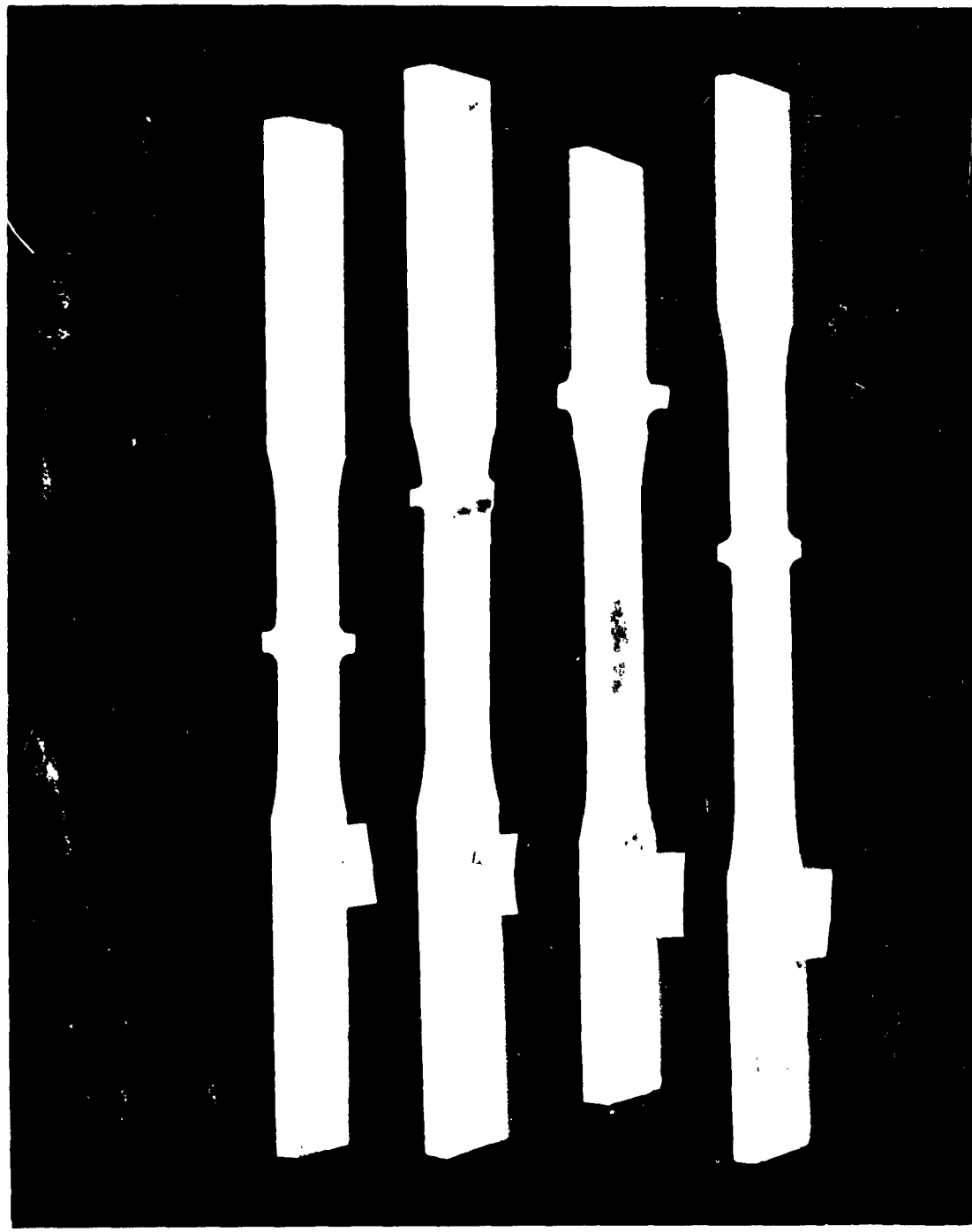

FIGURE 9. COUPONS 20, 21, 25, & 26 (SHOWING DYE INDICATIONS)

FIGURE 10. COUPONS 27-29 (SHOWING DYE INDICATIONS)

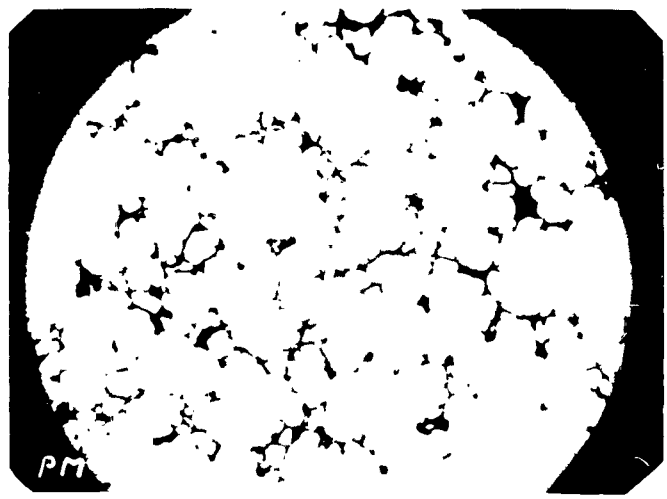

FIGURE 11. "SEVERE" SHRINKAGE POROSITY (SPEC. No.13)

MAG: 100X UNETCHED

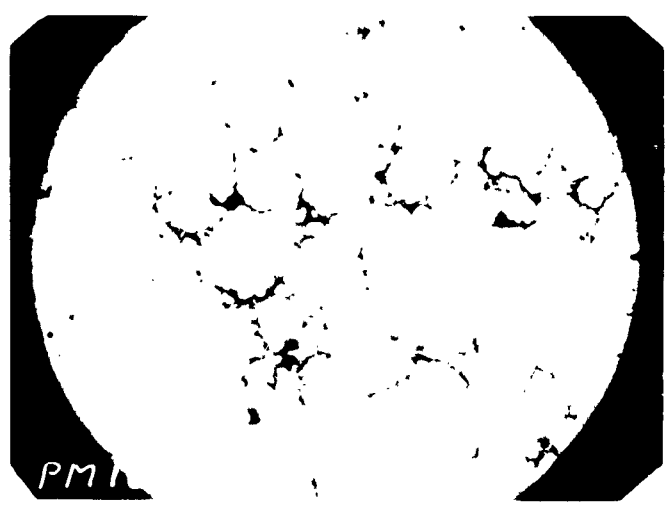

FIGURE "MODERATE TO SEVERE" CONDITION (SPEC.No.7)

MAG: 100X UNETCHED

FIGURE 13. "MODERATE" CONDITION (SPEC. No. 28)

MAG: 100X UNETCHED

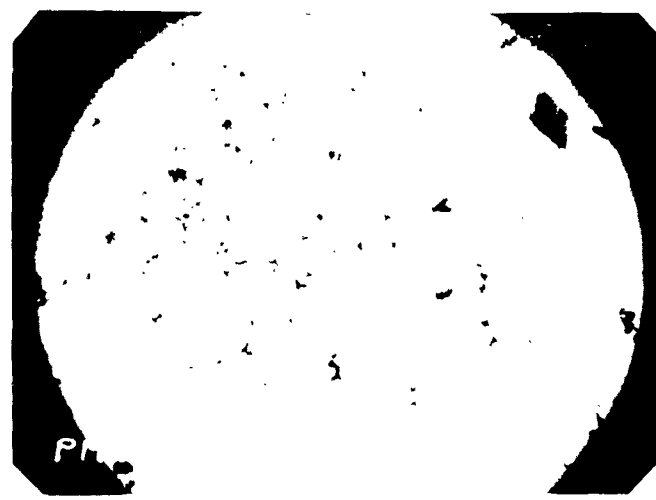

FIGURE 14. "SLIGHT" CONDITION (SPEC. NO. 14)

MAG: 100X UNETCHED

FIGURE 15. "SEVERE-LOCALIZED" CONDITION (SPEC.NO. 24)

MAG: 100X UNETCHED

FIGURE 16. "MODERATE-LOCALIZED" CONDITION (SPEC.NO. 9)

MAG: 100X UNETCHED

FIGURE 17. "TORN" CONDITION (SPEC. NO. 10)

MAG: 100X UNETCHED